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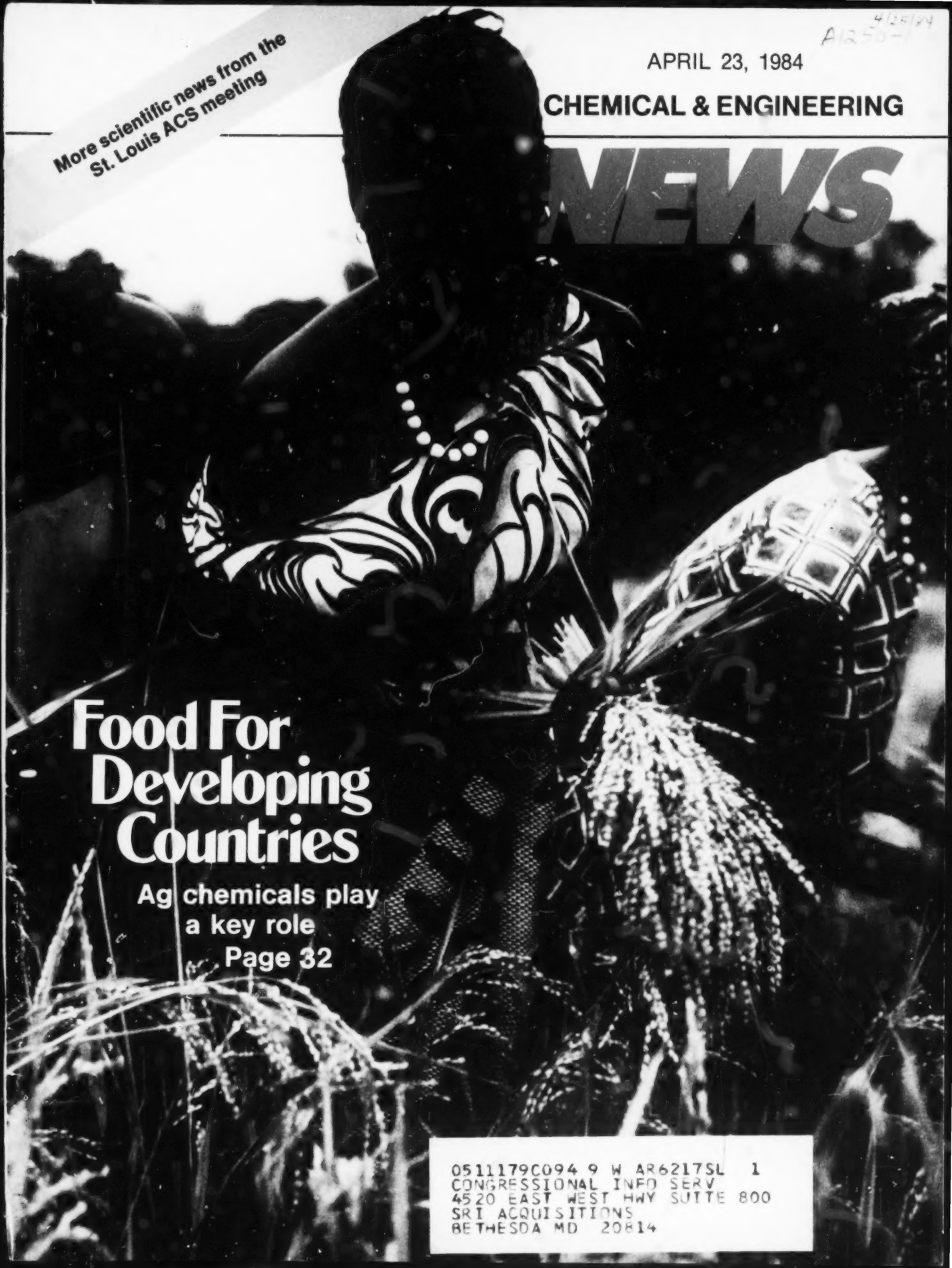
APRIL 23, 1984

CHEMICAL & ENGINEERING

NEWS

More scientific news from the St. Louis ACS meeting



Food For Developing Countries

Ag chemicals play a key role

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Cover: Woman in Casamance region of Senegal harvests rice by traditional method of cutting one stock at a time. Photo courtesy of World Bank

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CHEMICAL & ENGINEERING NEWS

APRIL 23, 1984

News of the Week

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Government

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Food needs in developing countries must be met by bigger crop yields, increased fertilizer and irrigation use. **Page 32**

Women Chemists Mortality Study Finds High Suicide Rate

Study of women ACS members from 1925 to 1979 finds five times expected rate of suicide, risk up for some cancers, low for heart diseases

National Meeting
St. Louis

Women chemists are substantially more likely to commit suicide than are other women in the U.S. of the same age, according to epidemiologist Judy Walrath of the National Cancer Institute. In a mortality study of 347 white women members of the American Chemical Society who died between 1925 and 1979, Walrath and her colleagues found that 36, or roughly one in 10, died by suicide. This is five times the number expected from a sample of this size based on statistics for white women in the U.S. as a whole.

The study, presented at the open session of the Women Chemists Committee, is not the first one to suggest that women chemists are particularly prone to suicide, Walrath says. A 1969 study directed by Frederick P. Li at the National Cancer Institute of deaths of men and women ACS members found that 11% of the 115 women in the study died by suicide. However, the number of women chemists in this study was fairly small, so the present study was undertaken to see whether the same trend would be found in a larger sample. Li is a coauthor of the new study, as is Joseph F. Fraumeni Jr., a clinical epidemiologist at the National Cancer Institute, and Marshall W. Mead, head of membership statistics and planning for ACS.

There was an increased incidence of suicide for all three time periods examined in the study—deaths that occurred before 1960, from 1960 to 1969, and from 1970 to 1979, Walrath says. The most common method of committing suicide was by cyanide poisoning (39%), followed by barbiturates (28%), and firearms (6%). This percentage of suicides by cyanide poisoning is high; typically only 6.4% of white female suicide victims use poisons of any sort other than barbiturates. The highest suicide incidence occurred among women chemists who were divorced or widowed, just as it does among women generally. However, married women chemists were more likely than single women to commit suicide, which is not true for women as a whole.

The study does not provide firm answers as to why the suicide rate is so high for women chemists. In fact, since it uses only death certificate data to establish the cause of death and membership in ACS as the criteria for being a chemist, it does not provide a great deal of information about the circumstances surrounding each particular death. Walrath suggests that most women who engage in chemistry work in a strongly male-dominated workplace, which may increase their level of depression. That, combined with access to chemical poisons, particularly cyanide, may be a factor in increasing their suicide rate. The 1969

Rates of suicide, certain cancers high for women chemists

Cause of death	Laboratory chemists		Academic chemists		Other chemists		All women chemists	
	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
All cancers	41	36.3	42	31.5	23	18.1	111	89.0
Digestive system	9	8.1	16	9.1	5	4.5	29[a]	21.1
Respiratory system	2	3.2	2	2.4	1	1.5	5	7.4
Breast	13	8.8	9	6.8	6	4.3	30	20.6
Ovary	3	2.9	5	2.3	5	1.4	13	6.7
Lymphatic and hematopoietic systems	6	3.2	4	2.5	3	1.4	13	7.4
Suicide	20	3.5	12	2.0	4	1.3	36	7.1
Circulatory system diseases	35	46.8	59	89.9	23	28.6	119	149.1
All causes	129	129.0	141	141.0	66	66.0	347	347.0

Note: Pairs in boldface show a statistically significant difference at the 0.05 level. Data are from study of white women members of the American Chemical Society who died from 1925 to 1979, based on information from death certificates. a For stomach cancer alone, the women chemists had a statistically significant excess incidence (8 observations compared to 3.8 expected).

study shows male chemists have a slightly elevated suicide rate, and studies of other professional women, such as physicians, registered nurses, and psychologists, also show some increased risk of suicide.

There may be other explanations, however. Mead suggests that some of the women who commit suicide may have life-threatening illnesses and choose suicide as a preferable way to die. This possibility is particularly worrisome, since it could distort the value of the study to pick up other occupationally related causes of death among women chemists. Another possibility that the report's authors would like to see studied further is a relationship between chemical exposures and psychological states predisposing to suicide.

Although it is in their suicide rate that the women chemists studied show the most striking difference from other women, the study finds other differences as well. Deaths from all cancers were elevated for the women chemists (111 observed vs. 89 expected). In particular, there were significant excesses of cancers of the stomach, breast, and ovary among the women chemists, as well as in deaths from leukemia, lymphoma, and other lymphatic system cancers. On the other hand, deaths from circulatory system diseases were significantly lower for women chemists than for women generally (119 observed vs. 149 expected). Overall, the death rate from all causes for the women in the study was exactly the same as for all white U.S. women of comparable age.

The study sample, which was comprised of all female ACS members known to have died between 1925 and 1979, also included 11 nonwhite women. These women showed no unusual mortality pattern, but the sample was too small for causes of death to be examined in much detail.

Occupational histories and records of exposure to any particular chemicals were not available for the women in the study. The researchers tried to assess whether chemical exposure was a factor in differences in mortality patterns by dividing the women chemists into three broad occupational categories: laboratory chemists, academic chemists, and others. They assumed that women in the first two groups would be exposed to chemicals and that those in the third group would not be. Although the number in each group was small, the researchers did find that the increase in stomach cancers seems to concentrate among academic chemists and ovarian cancer mortality among the women who were neither laboratory nor academic chemists. Suicide rates were elevated in all three categories, but were more pronounced among laboratory and academic chemists than among the others.

Some of the high levels of cancer incidence may have nothing to do with whether the women studied are chemists, Walrath explains. Breast cancer mortality, for example, was elevated only for women who had never married and who had joined ACS since 1935. This high incidence of breast cancer among women chemists who never married or never had children is consistent with increased risk among all women in these categories. Higher education and economic status also is associated with greater risk of breast cancer. Similarly, ovarian cancer mortality tends to be elevated among women who have never married, and the ACS sample has a large number of women in this group.

In the case of stomach cancer, however, the findings of the new study seem to be in contrast with trends reported in other studies. For instance, male ACS members in the 1969 study had a significantly decreased risk of stomach cancer. This cancer also is generally associated with lower socioeconomic status and is more common among foreign-born Americans. All of the women who died of stomach cancer in this study, however, were born in the U.S.

Increased stomach cancer risk has been reported for certain chemical-related occupations, such as workers in petroleum refineries, the rubber industry, and agricultural jobs. Dietary factors also are thought to play an important role. The present study could not evaluate the effects of either of these factors. □

New drugs for treating congestive heart failure

National Meeting
St. Louis

Agents now under development or already in clinical trials show promise for treating congestive heart failure, according to a number of speakers at a symposium sponsored by the Division of Medicinal Chemistry.

Congestive heart failure is a debilitating disease unique to humans in which the heart is unable, for one or more of a number of related reasons, to deliver an adequate supply of blood to meet the metabolic needs of the body. As pointed out at the symposium, digitalis has been recognized for 200 years as a positive inotropic agent—that is, a compound that increases the strength of heart muscle contraction. However, in treating congestive heart failure, digitalis and its analogs have only a limited effect and cannot be used by many patients because of adverse side effects.

Symposium speakers described a number of new inotropic drugs that can be administered orally. All of the drugs appear to act by a mechanism different from that of digitalis.

Richard A. Schnettler and Richard C. Dage, both researchers at Merrell Dow Research Institute, Cincinnati, described the chemistry and pharmacology of imidazolones, two of which Merrell Dow now has in clinical testing. A positive inotropic effect for imidazole was first reported in 1970, Schnettler says.

According to Dage, fenoximone and a related compound designated MDL 19,205 are orally active. In studies on dogs, the compounds increase the contractile force of heart muscle. In an isolated heart and lung preparation, the researchers observed an increase in muscle contractile force and a smaller, but significant, increase in heart rate

Jury Still Out on Adapting Western Processes for Eastern Shale

Studies of processes used to process western oil shale reach conflicting conclusions, whereas some new retorting methods look good for both

National Meeting
St. Louis

Eastern oil shale is known to be different from western shale. Whether that means that the processes used for western shale are adaptable for processing eastern shale remains to be seen. However, one evaluation of five existing processes indicates that, generally, processing requirements for eastern shale are different, though processes for western shale do produce usable products, and the general retort chemistry is similar for both types of shale.

Other, independent evaluations of particular processes, on the other hand, suggest that adaptation is less difficult than first suspected. And, there are also some new retorting processes that may be not only effective for eastern shale but improvements on those now in use in the West.

The adaptability of five retorting processes now used for western shale has been evaluated by a group at Los Alamos National Laboratory. William J. Parkinson, a Los Alamos staff member, told the Division of Petroleum Chemistry that the five processes included HYTORT (Institute of Gas Technology), Paraho C-H (combination heated), Paraho D-H (direct heated), TOSCO II, and a shale-fired power plant.

The HYTORT process uses a 90 mole % hydrogen recycle and operates at a pressure of 500 psig to increase oil yield. Paraho C-H combines the shale heating and combustion in a single step. However, the process usually needs large quantities of oxygen and diluent gases to burn off residual carbon and quench combustion. TOSCO II discards a lot of residual carbon in the spent shale. Paraho D-H also discards a lot of residual carbon and requires postretort gas cleanup. The shale-fired power plant was entirely simulated.

The evaluation assumed a nominal production of 50,000 barrels per stream day and that all plants would be located near a mine where shale could be purchased at $4.00 per ton. Although there are clear indications of the relative performance from each process, there is also considerable uncertainty in some of the cost data available to the evaluators. Of particular note are discrepancies in the data on retort costs. In all cases, the cost of acid gas removal is high, and the same cleanup techniques are not appropriate to all. Parkinson says that gas cleanup costs for the Paraho D-H processes are unusually high because the process produces large amounts of low-Btu sour gas.

One of the biggest differences between eastern and western shales is the lower hydrogen-to-carbon ratio of eastern shale. This presents a greater hydrotreating effort to produce an oil acceptable to refiners. It is also the basis for much of the adaptability problems with western technology.

The general conclusions reached by Parkinson and his associates were that western shale retorting processes are not adequate for use in the East, that the HYTORT process is the best of those evaluated, and that the Paraho C-H and TOSCO II processes can be greatly improved.

A difference of opinion was registered by Michael J. Roberts, manager of oil shale operations at the Institute of Gas Technology. IGT designed the HYTORT process and recently has been doing adaptation studies for Hycrude Corp. funded by Phillips Petroleum Co. A series of small pilot studies at IGT show that oil yields can be increased up to 230% of the Fischer assay yield from New Albany shale, a type typical of the eastern shales. The yield is a direct function of the hydrogen partial pressure. The actual hydrogen pressure to be used will be an economic compromise between yield and pressure.

The indications are that, with suitable design modifications, at least one existing process is adaptable to processing eastern shale.

A new way to process shales, east-

HYTORT is best of processes evaluated on eastern shale

Process	Product cost ($ per bbl)	Total capital ($ millions)	Oil production (bbl per stream day)	Operating cost ($ millions)	By-product income ($ millions)
HYTORT (IGT)	$ 48	$2188	58,575	$428	$ 63
Paraho C-H	70	2220	34,740	391	160
TOSCO II	75	2240	36,620	390	69
Paraho D-H	106	3140	29,220	428	221
Power plant	107	577	7,277	50	None

ern and western, may be the molten salt bath. Although emphasis will probably be on producing a substitute crude oil for further refining into conventional products, the possibility exists that other products also may issue from molten salt reactors.

One type of salt bath has been under investigation by a group at Los Alamos National Laboratory and was described by Cheryl K. Rofer-DePoorter. She noted that all the processes currently under consideration involve high-temperature pyrolysis and all have similar problems—namely, they require the handling of a lot of solids, they don't recover a lot of the available carbon in the shale, and they produce only a substitute crude oil that requires considerable refinery upgrading.

Molten salt baths generally operate at lower temperatures than retorts and thereby reduce some of the problems. A lengthy search produced a candidate molten salt with the formula 1NaOH:1KOH:-0.5LiOH.

Several samples of oil shale, subbituminous coal, wood sawdust, and tar sand were processed in the molten salt bath at 200 °C. Samples also were treated without the molten salts. Processing with the hydroxide doubled condensate yield from the coal and tripled the yield from sawdust. In addition, the sawdust was converted almost entirely to water-soluble products. The effects of the hydroxide on the tar sand were negligible.

Although the shales used in the molten salt experiments were all western shales, the investigators see no reason why eastern shales should not react similarly. The use of the molten salt reactor is also more generally applicable to most feeds, excepting tar sand. Why this should be so isn't known. A mechanism that is consistent with the observations has been suggested: oxidative attack on the kerogen to form carboxylic acid salts, followed by decarboxylation of the salts to hydrocarbons. Dissolution of mineral matter in the shale is a problem and appears to be temperature dependent. No sulfur or nitrogen appears in the products. □

Cutting carbonyl group stabilizes weedkiller

National Meeting
St. Louis

It's hard to invent a good herbicide, let alone bring it to market. Evidence for that hypothesis was offered to the Division of Pesticide Chemistry by chemists from FMC Corp.'s agricultural chemical group at Princeton, N.J.

The work that led to FMC's Command, a new broad-spectrum herbicide for pre-emergent weed control in soybeans, was the topic of four presentations. Command is the first commercial member of a new class of herbicides, the 3-isoxazolidinones. FMC chemists Marvin J. Konz, Jun H. Chang, Sayed A. Aly, James A. Kerschen, and John P. Kolsevich, together with research managers Kenneth Wilson and William A. Van Saun, have been involved in their development.

Describing the work that led to the discovery of the new herbicides, Konz and Chang noted that related compounds, the isoxazolidinediones, have been of interest to pharmacologists because of their analgesic, local anesthetic, and anti-inflammatory properties. Although there had been no reports of herbicidal activity, such heterocyclic ring systems are important constituents of many herbicides. So FMC undertook a synthesis program to investigate the weed-control potential of the class, particularly the 2-aryl- and 2-phenylmethylisoxazolidinediones.

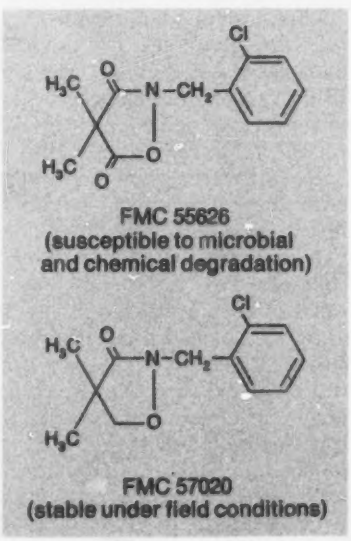
Several compounds were synthesized; one of them, 2-[2-(chlorophenyl) methyl] -4,4- dimethylisoxazolidine-3,5-dione (given the code name FMC 55626), showed great promise in greenhouse experiments. Used as a pre-emergent herbicide, FMC 55626 caused weed seedlings to emerge bleached, rather than green, and the effect was severe enough to kill the weeds. Most crop plants, including cotton, corn, and wheat, couldn't tolerate the herbicide either. Soybeans, however, were unaffected.

Later field tests brought bad news. Germinating weed seedlings were bleached, just as in the greenhouse, but they rapidly outgrew the condition and survived. Weed control was minimal, even for sensitive species. This suggested that FMC 55626 was susceptible to microbial and chemical degradation leading to loss of herbicidal activity; tests showed that that was indeed the case. In particular, the compound rapidly decomposed under mildly basic conditions, as a result of a decarboxylation reaction.

The original promise of FMC 55626 was so great, however, that Konz, Chang, Aly, Kerschen, and Kolsevich mounted a broad investigation of structure/activity relationship. The aim was to improve stability while retaining herbicidal activity. The project involved extensive structural variations of the heterocyclic ring and substituent variations on the aromatic ring. For example, experiments with isoxazolidinethiones and isoxazolin-3(2H)-ones revealed much about the electronic and structural requirements for biological activity. The studies also indicated that the compounds work by affecting carotene and chlorophyll synthesis in susceptible plants.

One of the questions that had arisen early in the study of FMC 55626 was how important were the two

Carbonyl group causes instability in compound



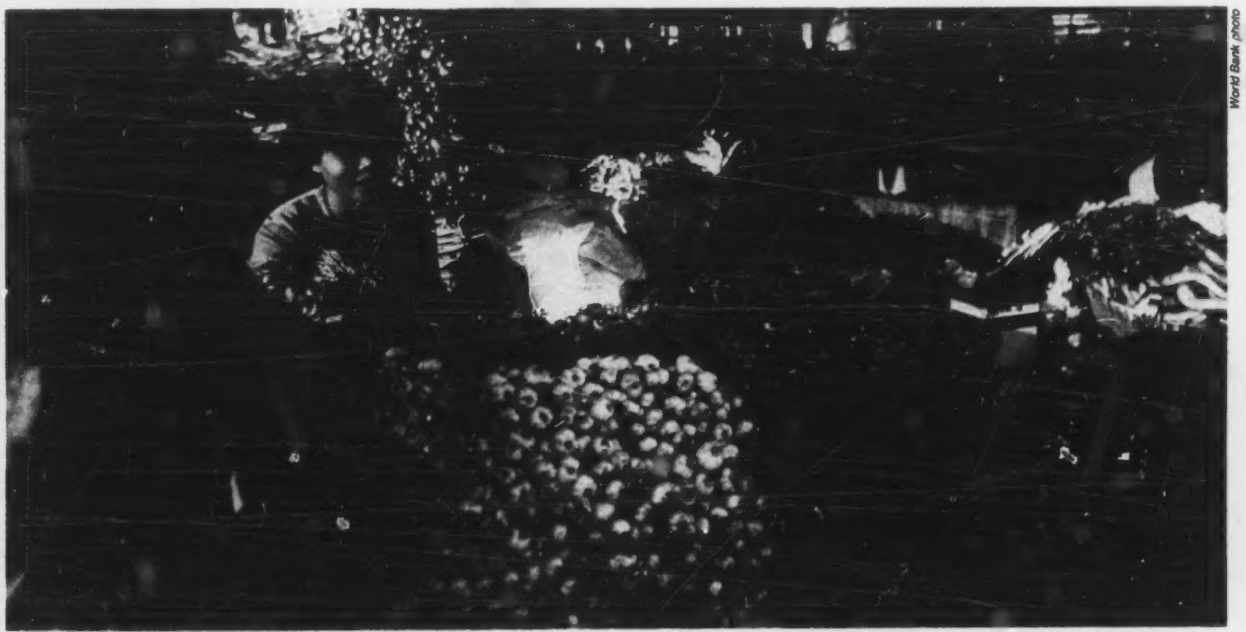
Feeding The Underdeveloped World

Chemical technology is crucial in alleviating poverty and hunger

John W. Mellor and Richard H. Adams Jr.
International Food Policy Research Institute

Social, economic, and humanitarian concerns dictate the need for a rapid increase in food production in the developing countries. Although authoritative figures are lacking, the National Academy of Sciences estimates that more than 450 million people in the world are hungry and malnourished. Most of them live in the developing countries of Asia, Africa, and Latin America, where technological and chemical inputs required for increased food production still have to make considerable headway.

Between 1961 and 1980, food production in the de-



World Bank photo

Markets, like this one in Thailand, are better stocked in many developing countries, thanks to progress in agricultural technology. But growth in population and income means that demand for food often outruns production

veloping world increased at an average rate of 2.6% a year. This was slightly greater than the average annual population growth rate of 2.4%. On a per capita basis, food production in the developing countries as a whole increased only 0.2% a year. In Sub-Saharan Africa, per capita food production actually declined a shocking 1.1% a year.

Such disappointing growth rates call attention to the pressing need for technological and chemical improvements in developing countries' agriculture. Technological inputs (such as high-yield seeds and irrigation systems) and chemical inputs (including fertilizers and pesticides) play a critical role in virtually all modern methods of agriculture. In general, field studies suggest that each kilogram of fertilizer nutrients produces an average yield increase of 10 kg of grain in the developing world. And research at the International Rice Research Institute in the Philippines indicates that rice plots protected by insecticides yield almost twice as much as unprotected plots. Such yield-increasing inputs are needed to meet the burgeoning developing world's food requirements.

Population growth and rising per capita income are the two principal forces underlying the ever-increasing demand for food in the developing countries. In less-developed societies, as elsewhere, population growth fuels a steady increase in the demand for food. Such increased demand often can be met with more physical effort on a slightly larger land base. But in more dynamic societies, income growth fuels an explosive surge in the demand for food that typically exceeds the production capabilities of traditional agriculture.

Income growth accelerates food consumption because of what economists call the "high-income elasticity of demand" for foodstuffs. In the developing countries, low-income people spend the bulk of their income on food. In India, for example, the laboring class spends 60% of its income increments on grain and nearly 80% on food products as a whole. Hence, any improvement in the purchasing power of the poor has a dramatic effect on their demand for food.

Faced with growing food shortages at home, many rapidly developing countries have come to rely on greater food imports.

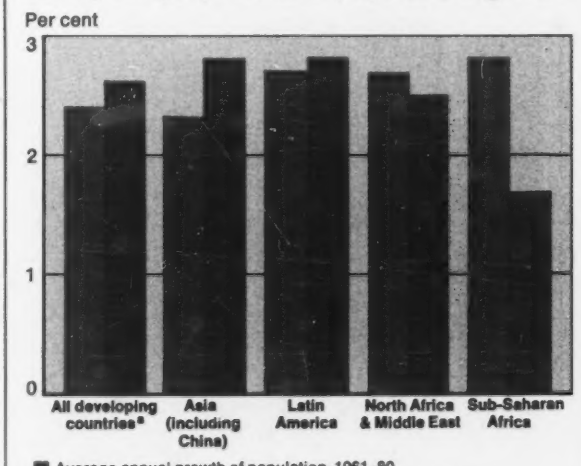
The growing dependence of many developing countries on food imports is easily demonstrated. Between the years 1966–70 and 1976–80, food imports to these nations as a whole rose at an average annual rate of 6.4%. Fueled by the high rates of income growth in the oil-exporting countries, food imports to developing countries in North Africa and the Middle East grew an unprecedented 11.3% a year. But even in the poor, drought-stricken countries of Sub-Saharan Africa, food imports increased at an average rate of 9.2% a year.

Rising food import costs in most developing countries provide an added incentive for new technological investment in agriculture. Food production presently is languishing in many developing countries because their governments are reluctant to allocate sufficient funds to the basic building blocks of agricultural development: agricultural research, agricultural extension services, rural roads, and public and private services.

For example, in Africa, a continent where per capita food production currently is declining, the average share of government spending on agriculture is only 7.6% of the total government budget. By comparison, in the Indian state of Punjab, an area where food production has grown very rapidly in recent years, the local government has allocated 11% of its budget to agriculture. This state allocation in Punjab supplements an equally high national government allocation.

In many developing countries, low government investment in agriculture reflects a relatively low priority assigned to the agricultural sector. The leadership in many developing countries has tended to equate development with industrialization, especially heavy industrialization, and generally to overlook the important role that agriculture can play in fostering industrialization. Striking exceptions to this pattern of development include Japan and Taiwan in the early part of this century and Punjab in more recent years. In these cases,

Developing countries' food production barely keeps pace with population growth



a Includes 105 Asian, African, Middle Eastern, and Latin American countries. b Includes cereals, roots and tubers, pulses, groundnuts, bananas, and plantains. **Sources:** United Nations Food & Agriculture Organization, International Food Policy Research Institute

Developing countries are becoming more dependent on food imports

	Average annual imports of major food crops[a]		% average annual growth of imports, 1966–70 to 1976–80
	1966–70	1976–80	
	(millions of metric tons)		
Developing countries	41.1	76.7	6.4%
Asia (including China)	24.0	32.5	3.1
North Africa and Middle East	7.0	20.4	11.3
Sub-Saharan Africa	2.4	5.8	9.2
Latin America	7.8	18.0	8.7

a Includes cereals, roots and tubers, pulses, groundnuts, bananas, and plantains. Rice is in terms of the milled form. **Sources:** United Nations Food & Agriculture Organization, International Food Policy Research Institute

high levels of public investment in agriculture have increased food production and encouraged agricultural and industrial development.

The principal ways of boosting food production in the developing countries are by expanding the area of cropped land and by increasing crop yields.

In comparing these two approaches, Perry L. Adkisson, deputy chancellor for agriculture at Texas A&M University, says, "Increases in the area of cropped land probably will not exceed an average of 1% per year over the next 25 years and could be much less. Thus, much of the production increases need to come from increased yields. Increases in yields need to average 2.5% per year [in order to meet food demand in the developing countries]."

Rising crop yields have become the main source of growth in food production in the developing nations in recent years. Between 1961 and 1980, output per hectare of major food crops in the developing world increased an average of 1.9% annually, accounting for more than 70% of total food production growth. Increases in the harvested area averaged only 0.7% a year and contributed the other 30%.

Increases in yields require prolonged and continuous technological change in agriculture. Depending on the particular situation, improvements in agricultural technology (such as use of high-yield seeds, fertilizers, and pesticides) produce yields two to four times higher than those achieved by traditional means. For example, the adoption of new technology in India increased average cereal yields 29% between the periods 1954–55 through 1964–65 and 1967–68 through 1977–78. Such impressive increases in yield now are needed in other developing countries.

Fertilizers play a key role in most efforts to stimulate food production in developing countries. Although the exact effects of fertilizers on total production depend on a variety of factors, many studies show their value. For example, a study by Mohinder S. Mudahar of the International Fertilizer Development Center and by Per Pinstrup-Andersen of the International Food Policy Research Institute found that increased use of fertilizer accounted for 30% of the increase in cereal grain production in the developing countries during the periods 1948–52 to 1972–73.

Such findings underscore the importance of recent trends in fertilizer use. Between 1950 and 1982, the developing countries' share of total world fertilizer consumption more than quadrupled. In 1950, total fertilizer use in the developing world stood at less than 1 million metric tons of nutrients. By 1982, this figure had risen to about 38 million metric tons.

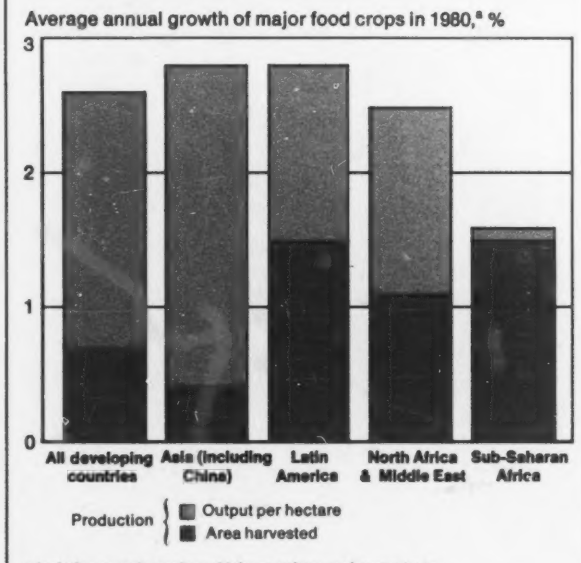
Much of this phenomenal growth occurred during the past decade. Between 1970 and 1980, fertilizer consumption in the world's developing countries increased by more than 20 million metric tons of nutrients, compared to 13 million metric tons in the preceding two decades.

Despite such recent gains, use of fertilizer in the developing world still remains quite low. Though variations in soil fertility and cropping patterns make it difficult to compare different areas, fertilizer use per hectare in the developing world still remains only 17% of that in the industrialized countries. According to the United Nations Food & Agriculture Organization (FAO), fertilizer consumption in developing countries must rise nearly fivefold by the year 2000 to meet their growing demand for food.

Within the developing countries, fertilizer use per hectare is lowest in Africa and highest in Latin America. But even within these areas, the range of use varies considerably among countries—for example, from 4.0 to 180.0 kg per hectare in Latin America and from 3.0 to 318.0 kg per hectare in Asia. Compared to levels in some European countries, such as 740 kg per hectare in the Netherlands, fertilizer use in the developing countries has a large potential for growth.

Much of this growth will have to be supplied by im-

Rising crop yields spur food production in the developing countries



a Includes cereals, roots and tubers, pulses, and groundnuts.
Sources: United Nations Food & Agriculture Organization, International Food Policy Research Institute

Consultative Group on International Agricultural Research (CGIAR) photo

Cassava tubers such as these, an important local source of starch, have been improved by breeding experiments at Nigeria's International Institute of Tropical Agriculture

ports. In 1980, the developing countries imported 38% of their total fertilizer requirements. This is only a modest decrease from 1970, when they imported 44%. Although production self-sufficiency probably will continue to rise in the developing world, many African and Asian countries will remain heavily dependent on imports from a handful of countries—Canada, the U.S., West Germany, East Germany, and the Soviet Union.

Gunvant M. Desai, a fertilizer expert at the Indian Institute of Management, notes that growth in fertilizer consumption in the developing countries "depends on a number of factors. On the supply side, mechanisms for producing, importing, and distributing fertilizer at the farm level must be developed. On the demand side, systems of research, extension [service], and credit must be established to increase farmers' demand for this input."

According to Desai, pressure from the supply side—that is, the increased availability of fertilizers—has been an important factor underlying growth in worldwide consumption. After World War II, the war-related surplus in ammonia capacity in the U.S. and other developed countries stimulated fertilizer consumption in a number of industrialized countries.

In the 1950s and 1960s, these surpluses also played a leading role in initiating fertilizer use in many developing countries. Foreign-aid programs to encourage fertilizer use grew apace. These factors help explain the more than 1500% expansion in fertilizer use in developing countries since 1960.

At present, most major developing countries produce at least some fertilizer. This reflects their desire to gain greater control over their supply of fertilizers, particularly in view of the increases in world fertilizer prices in the 1970s. Although fertilizer prices have declined in more recent years, average annual real prices between 1970 and 1980 (after allowing for inflation) rose 41% for urea fertilizers, whereas those for triple superphosphate fertilizers increased 28%.

In many developing countries, fertilizer production is curtailed by a variety of factors, including an unreliable supply of raw materials, recurring shortages of spare parts for machinery, and a scarcity of trained managerial personnel. Currently, fertilizer plants in the developing countries are being used at an average of only about 60% of capacity, even though fertilizers in many places are in short supply.

Improving the marketing and distribution facilities in rural villages could do much to stimulate the consumption of fertilizers in these countries. Experience indicates that fertilizer use never begins among all farmers and crops simultaneously. Rather, it typically starts among a small group of farmers who grow cash crops. In time, the number of farmers using fertilizers widens as local extension agents convince them of the considerable benefits of fertilizer.

Over the long term, sustained growth in fertilizer

Fertilizer subsidies far outweigh agricultural research in developing world

	Spending on fertilizer subsidies, 1969–75 ($ millions)	Spending on agricultural research, 1969–75 ($ millions)	Fertilizer subsidies as a proportion of agricultural research spending, 1969–75, %
DEVELOPED COUNTRIES			
Australia	$110.49	$113.90	97%
Austria	2.11	4.50	47
Greece	4.79	4.57	105
New Zealand	27.07	28.60	95
U.K.	75.38	60.20	125
DEVELOPING COUNTRIES			
Afghanistan	$ 15.10	$ 0.63	2397%
Bangladesh	14.63	1.40	1045
Indonesia	71.90	3.42	2102
Pakistan	20.97	1.26	1664
South Korea	27.26	2.44	1117

Source: Mohinder S. Mudahar and Per Pinstrup-Andersen, "Fertilizer Policy Issues and Implications for Developing Countries," January 1979

CGIAR photo

Greater rice production as here in Thailand depends on reliable water supplies as well as on quicker-maturing, higher-yielding varieties of seed

consumption in the developing countries requires the creation of new demand. This is primarily the responsibility of national agricultural research and extension systems. Developing countries, such as Taiwan and India, with their well-financed and well-staffed research and extension programs, can develop and disseminate the new high-yield seeds and irrigation techniques that serve to increase demand for fertilizers.

The role of agricultural research in stimulating local demand for fertilizers often is neglected. Research in Asia demonstrates that the technological advances made by national research organizations, such as the introduction of new crops and improved irrigation facilities, have been major determinants of growth in demand for fertilizers. A study by Yujiro Hayami of Tokyo Metropolitan University shows that 70% of the increase in commercial fertilizer use in Japan between 1883 and 1937 is explained by technological progress in agriculture and only 30% by lower prices.

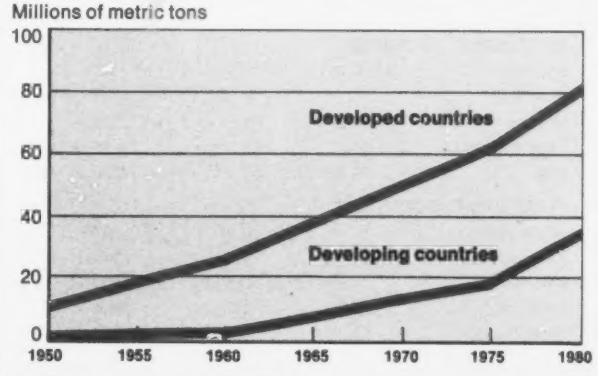
To promote fertilizer use, many developing countries' governments try to reduce prices through subsidies. According to FAO, nearly two thirds of all developing countries had fertilizer subsidy programs, at least part of the time, between 1969 and 1980. Since these programs usually begin when consumption is low, their initial costs are quite manageable. However, as use rises, so do costs. Allowed to grow unchecked, fertilizer subsidy programs can become a significant burden on government resources.

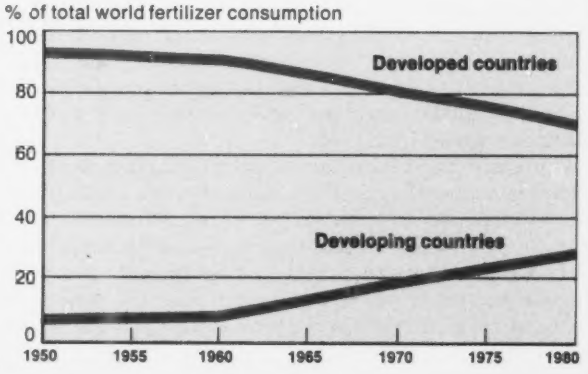
It is instructive to compare the relationship between government spending on fertilizer subsidies and agricultural research in various developed and developing countries. In Australia, Greece, and New Zealand, for example, government spending on fertilizer subsidies was about equal to that spent on agricultural research between 1969 and 1975. But in the developing countries of Afghanistan, Indonesia, and Pakistan, government spending on subsidies ranged between 1600 and 2400% of the amount spent on agricultural research.

This is a serious misallocation of government funds. Economic returns on subsidies are relatively short term, but investment in research generates a stream of economic returns for an indefinite period. According to recent studies by agricultural economists, the annual rate of return on investment in agricultural research ranges from 20 to 90%, with an overall average of 48%.

If the objective is to increase food production, it would seem that much more attention should be paid to improving agricultural research organizations and extension services in the developing countries. Effective national research organizations provide the means for developing high-yield seeds, fertilizers, and pesticides

Consumption of fertilizers grows fastest in the developing countries





Source: FAO Fertilizer Yearbooks, 1950–80

that are adapted to local conditions. In turn, the establishment of efficient, local extension services provides the means for disseminating these new technological inputs to farmers.

In recent years, many developing countries have taken steps to upgrade their agricultural research. A joint study by the International Service for National Agricultural Research and by the International Food Policy Research Institute indicates that real government spending on agricultural research in the developing countries has increased 70% since 1975. Yet much still remains to be done. More than 60% of all national expenditures on agricultural research in the developing world are concentrated in just five countries—Argentina, Brazil, India, Mexico, and Nigeria. Agricultural research still remains in a comparative state of infancy in many Asian, African, and Latin American countries.

Role of irrigation

In many developing countries, expansion of irrigated land has led to some of the largest increases in food production. D. Gale Johnson, chairman of the economics department at the University of Chicago, says, "Depending on the particular situation, irrigated land yields from two to four times as much [food] as the same land before it was irrigated. Thus, irrigating 1 hectare of land is the same as 'finding' 1 to 3 additional hectares of cropland."

In almost all developing countries, great potential exists for increasing irrigation. However, major projects require considerable lead time, as well as administrative cooperation in planning and construction. They also call for very large capital investments. A recent study by the International Food Policy Research Institute estimates that the total capital costs of producing the additional food crops needed to feed the developing countries in 1990 would be $98 billion. Almost half of these costs would go for developing new water resources.

Irrigation can increase cropping intensity (the number of crops produced per year) in areas where lack of water has limited production in the past. In many semiarid countries, for instance, effective irrigation systems could enable farmers to produce two crops a year where they now grow only one. Throughout the developing countries, increased cropping intensity is an important means of meeting the urgent need for more food.

Irrigation also can raise the income of peasant farmers. A study by Clive L. Bell of the World Bank and Peter B. R. Hazell of the International Food Policy Research Institute found that the incomes of 51,000 farm households in Malaysia nearly doubled in the seven years after a large irrigation project was completed. According to these researchers, investment in irrigation causes large increases in the incomes of land-owning farmers, who spend much of their new income on a wide range of local goods and services. In turn, the production of these goods and services expands employment and income opportunities for landless farmers and nonagricultural workers.

Many of the benefits of irrigation come about through its use together with new chemical and technological inputs in agriculture. Reliable water supplies, for example, are needed to grow high-yield seed varieties effectively. In Malaysia, irrigation facilitated double-cropping and the introduction of quicker-maturing, higher-yielding varieties of rice. And recent research in India shows that expansions in irrigation and fertilizer use are closely related. Only about one fourth of the total cultivated area in India is irrigated, but about 70% of all fertilizer is used on irrigated land. In addition, the rates of fertilizer application on India's irrigated land are about twice as high as those on unirrigated land.

World Bank photo

Agricultural research, such as this work on pollinating rice in the Philippines, is increasing in many developing countries, but remains in its infancy

Pesticides

Whereas expanded irrigation systems and fertilizer use stimulate food production in the developing countries, pesticides help to preserve the benefits of increased production. Pests such as insects, weeds, fungi, and so on cause high crop losses. For example, David Pimentel, professor of insect ecology and agricultural science at Cornell University, estimates that "total worldwide food losses from pests amount to about 45% [of total food production]. Preharvest losses from insects, plant pathogens, and weeds amount to about 30%. Additional postharvest losses from microorganisms, insects, and rodents range from about 10 to 15%."

Field experiments in the developing countries already have demonstrated the ability of pesticides to promote food production. For example, use of herbicides on experimental farms in Turkey increased wheat yields 64%.

Although research results are not always matched in

World Bank photos

Food imports, such as this grain being unloaded at Dakar, continue to rise in much of the underdeveloped world

farmers' fields, the benefits of using pesticides are not merely theoretical. These benefits of pesticide use are especially important to countries that rely heavily on agricultural exports. In Ghana, for instance, where cocoa exports provide some 60% of foreign exchange earnings, use of insecticides to control capsid bugs has helped increase cocoa yields up to 244%.

Currently, developing countries use about 20% of the world's total pesticide production, with consumption heavily concentrated in three large countries: Brazil, India, and Mexico. Average annual pesticide use in the developing countries is about 100 g per person, considerably less than in the industrialized countries. But the picture is changing; the value of developing countries' imports of pesticides grew at an average annual rate of 15% between 1974 and 1980.

Although the benefits of pesticides are undeniable, much attention in recent years has focused on their considerable social and environmental costs. Human poisonings are clearly the highest price paid for using pesticides.

In many developing countries, improper use of pesticides by untrained workers often leads to poisoning during application. Also, workers who enter treated areas too soon after treatment to weed or harvest crops are exposed to the pesticide by brushing against contaminated foliage. This has been the primary means of pesticide exposure among field workers in Central America. Although exact figures are unavailable, it has been estimated that in certain Central American countries (Guatemala, El Salvador, Honduras, and Nicaragua) a total of about 3000 to 4000 pesticide poisonings occur annually. About 10% are fatal.

By disrupting natural controls, pesticides also can have a detrimental impact on the environment. For example, many insect and mite populations remain as minor or unimportant pests in crops because natural enemies control them. When pesticides are used against one pest, its natural enemies may be reduced or eliminated. This has contributed to outbreaks of pests that previously were not a problem. For example, the use of the fungicide benomyl to control fungi in soybeans may unleash damaging outbreaks of foliage-feeding caterpillars that the fungi might otherwise have destroyed.

When outbreaks of new pests occur, additional control treatments must be used. This is particularly true in the humid tropics, where frequent and heavy rainfall creates a need for additional chemical sprayings. In these areas, the cost of such additional treatments often is so high that they become uneconomical, even though they increase crop yields.

The undesirable side effects of pesticides on the environment—in particular, their adverse effects on lower organisms needed as food by higher organisms—have led many experts to question the efficacy of an overreliance on chemical controls. Hence, there is much current interest in integrated pest management. Chemicals may well provide the basis for an integrated manage-

Use of pesticides, as on this field being sprayed in India, helps preserve agricultural production in developing nations but poses serious health and environmental hazards

ment program—but chemicals used in such a way as to complement biological and agricultural controls.

In many developing countries, biological and agricultural control methods already represent the dominant form of pest control. Crop rotation, soil and water management, and the manipulation of planting dates have long been used throughout the developing countries to reduce pest outbreaks. For example, planting corn in rotation after such crops as soybeans and wheat can effectively reduce the incidence of corn rootworm.

In recent years, plant breeders have sought to extend the efficacy of such nonchemical controls by developing host plant resistance in major crops. Thus, after recent ravages of the brown planthopper in southern Asia, scientists at the International Rice Research Institute successfully developed a new variety of rice (IR-36) resistant to this insect.

A look into the future

The closing decades of this century, we believe, will see large numbers of developing countries undergoing rapid economic development. The ever-rising demand for food in these countries will place increasing pressure on them to boost their food production.

Under these circumstances, most developing countries would be well advised to place far greater emphasis on expanding agricultural production than they have in the past. Increased food output is important for continued economic growth and for the alleviation of poverty throughout the developing world. In most developing countries, accelerated growth in food production requires widespread use of technological and chemical inputs in agriculture.

The developed countries, of course, have a key role to play in helping developing nations achieve their food supply goals. Food from the developed countries is frequently essential in alleviating the shortages that occur when the domestic demand for food increases faster than local output. In addition, the developed countries have the funds and technical expertise needed by developing countries to improve their basic and applied agricultural research to expand their food production. Such assistance not only promotes steady economic growth but also relieves the serious food shortages that often accompany economic development.

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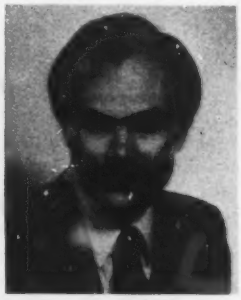

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